Journal of Korean Nature Vol. 4, No. 2 111-119, 2011

Journal of Korean Nature

Changes of fish community in the Mankyeong and the Dongjin River after construction of Saemangeum Dike

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Abstract: To monitor changes of fish assemblage, we selected 5 study sites in lower-middle part of the Mankyeong (3 sites) and the Dongjin (2 sites) River, and conducted field sampling 2 to 4 times per year from 2007 to 2009. Total sampled fishes were 66 species in 16 families. Cyprinidae (RA, 73.25%; 33 species) was dominant family. Dominant species was *Zacco platypus* (RA, 19.96%), and subdominant species was *Chelon haematocheilus* (RA, 11.11%). There were 18 Korean endemic species (RA, 12.56%) and one endangered species, *Liobagrus obesus*, was only found in the Mankyeong River. Three exotic species were found: *Carassius cuvieri, Micropterus salmoides and Lepomis macrochirus*. Fish assemblages showed similar occurrence patterns around the sampling periods. As a result of species number comparison between before and after dike construction at MR1 and MR2, there was no huge difference. When fishes were classified into two types, primary freshwater and peripheral species, using habitat characteristics, number of primary freshwater species was increased from 14 to 21 after dike construction. Moreover, relative occurrence rate of primary freshwater species was increased to 53% compared with before construction (18%). On the other hand, number of peripheral freshwater species was decreased from 29 to 19 after dike construction. As a result of cluster analysis using Jaccard method, fish community before and after dike construction was distinguished each other.

Keywords: *brackish water area, desalination, primary freshwater fish, dike construction, fish community*

Introduction

Fish are influenced by various factors related to the environment and their habitat (Buisson *et al*., 2007; Matthews and Robison, 1988; Matthews *et al*., 1992; Kouamélan *et al*., 2003). A wide range of developments have led to continuous changes in the ecosystem and have thus resulted in changes in the habitat of aquatic organisms. Under such circumstances, freshwater fish, which make up majority of the high trophic level of the freshwater ecosystem (Moyle and Cech, 2000) are also indirectly affected. Constructions, especially of dams, beams and estuary barrages, in river streams not only affect the habitat of fish, but also may affect their movement, and such constructions have resulted in significant changes in the regional fish communities (Barry, 1990; Mallen-Cooper and Harris, 1990).

Dikes are installed in order to prevent sea water from entering as either a result of the sea level being higher than ground level or as a result of tides. Dikes are constructed primarily in the Yellow Sea, where there is high tide difference and highly active reclamation projects, and large scale dikes include the Saemangeum Dike, Cheonsuman Dike, Asanman Dike, Shihwa Dike and Sapgyocheon Dike. Among these, the Saemangeum Dike, built between 1991 and 2006, is the longest dike in the world.

Although the dike construction serves positive purposes, such as freshwater securement and salt damage prevention, it also causes ecological changes by compartmentalizing brackish water zone into sea water and fresh water. Changes in salinity especially have significant effect on the fish species structure (Meng, 1973; Thiel *et al*., 1995).

Until recently, studies on the changes in fish community caused by large-scale installations constructed across water body have focused on dams (Kim and Yang, 2001; Seo and Kim, 2009) and estuary barrages (Yang *et al*., 2001; Kwak and Huh, 2003). In the case of dikes, studies on the changes in fish community included those conducted on the Asanman Dike (Lee, 1991; Lee, 1993), Cheonsuman Dike (Lee, 1996; Lee, 1998) and Saemangeum Dike (Lee *et al*., 2003), and these studies were conducted on sea water fish. A high level of dike constructions has taken place in Korea, which have resulted in a high level of environmental assessment as well. However, such studies rarely included

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long-term quantitative studies on fish community, and there is very limited number of studies on the changes in freshwater fish community of streams that flow into dike as a result of the dike construction. Therefore, this study was conducted in order to analyze the changes in freshwater fish of the Mankyeong River and the Dongjin River experiencing desalination following the Saemangeum Dike construction in order to secure comparative data and information regarding the changes in the freshwater fish community of area before and after the Saemangeum Dike construction.

Materials and Methods

Study sites

The Saemangeum Dike, included in the open sea of the Geum River Estuary, stretches over 33.9 km from Osik Island, Bieung Island, past the Mankyeong River and the Dongjin River to Gun island of Gogunsan, and is 36 m high with a surface area of 40,100 ha, making it the biggest dike in the world. Its construction began in 1991 and was completed on April 21st of 2006, and since then, seawater passes through only the sea dike sluice.

This study was conducted between 2 and 4 sessions per year between 2007 and 2009 in 5 study sites of the Mankyeong River (3 sites) and the Dongjin River (2 sites). Study sites included those which can be compared to previous studies, and site details, including the coordinates, are as follows.

St. 1: Mankyeong Bridge, Bokgyo-ri, Daeya-myeon, Gunsan-si, Jeollabuk-do (35°54'26.9"; 126°49'59.2")
St. 2: Mankyeong Bridge, Baekgu-myeon, Gimje-si, Jeollabuk-do (35°54'19.2"; 126°54'34.1")
St. 3: Samnye Bridge, Samnye-eup, Wanju-gun, Jeollabuk-do (35°53'55.5"; 127°04'35.6")
St. 4: Sintaein Bridge, Simtaein-eup, Jeongeup-si, Jeollabuk-do (35°45'29.4"; 126°46'44.6")
St. 5: Dongjin Bridge, Dongjin-myeon, Buan-gun, Jeollabuk-do (35°38'20.2"; 126°56'24.3")

Fish collection

Fish collection was conducted using stake nets (5×5 mm mesh) and cast nets (7×7 mm mesh; size 4.5 m^2). Over 10 collection were conducted in sites which were wide enough for cast nets usage, and collection using stake nets was conducted for over 30 minutes at each site in order to analyze fish species inhabiting each site.

Collected fish were determined for species at the site, individual counts were recorded, and those which were difficult to determine were fixed in 10% formaldehyde solution before being taken to a laboratory facility for further determination. Species determination was conducted using documents and systems by Kim and Park (2002) and Nelson (1994).

The fish were categorized as freshwater fish, peripheral fish and seawater fish for analysis, and freshwater fish included only species which spend their entire lifecycle in fresh water. Basic categorization was conducted using the fishbase document by Kim *et al*., (2005).

Documents by Kim and Lee (1984), Lee *et al*. (1980) and Lee (1990) were used as reference for the fish fauna prior to dike construction, and information regarding the fish fauna of St. 1 and St. 4, down streams of the Mankyeong River and the Dongjin River, which are predicted to have undergone changes in their fish fauna as a result of continuous desalination within the dike, were used for the comparative analysis of before and after dike.

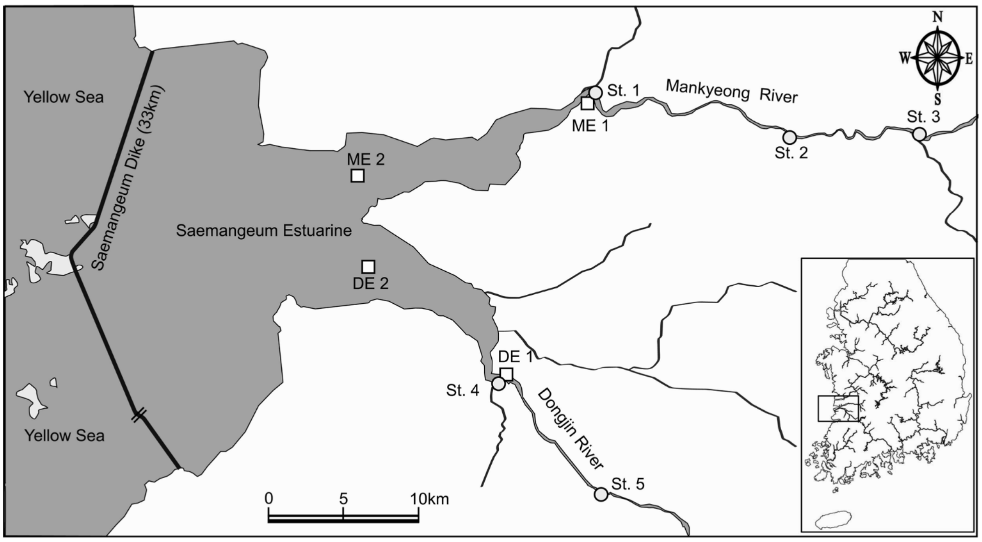

Fig. 1. The map of study sites.

Documents related to water quality (water temperature, dissolved oxygen, salinity) used in this study included a total of 4 water quality assessment documents (Inflow : ME 1, DE 1; lakes: ME 2, DE 2) currently being conducted by the Korea Rural Community Corporation (Fig. 1).

Data analysis

Dominance (Simpson's index, Simpson, 1949), Species Diversity (Shannon-Wiener index, Shannon and Wiener, 1949), Species Evenness (Pielou evenness index, Pielou, 1969) and Species Richness (Magalef index, Magalef, 1958) were calculated for the community structure analysis by site. Annual cluster analysis of the jaccard index (Jaccard similarity coefficient) for St. 1 and St. 4, downstream of the Mankyeong River and the Dongjin River, was used for the comparative analysis of fish fauna before and after the construction of the Saemangeum Dike, and analysis was conducted using Biodiversity pro 2.0.

Results

Water quality

The inflow stream sites displayed continuous increase in water quality between 2002 and 2009. The lake sites also displayed such improvement between 2000 and 2009, with the exception of the 1999 data (Fig. 2a). Dissolved oxygen displayed decrease in water quality in 2000, 2001 and 2005, but showed overall improvement following 2006 (Fig. 2b). In terms of salinity, lake sites displayed an overall level between 25% and 30%, a level which is similar to that of the sea (Fig. 2c). Changes by year did not show significant difference between the lake sites and the inflow stream sites, and the influx stream sites of DE 1 displayed high levels of variation among individual years.

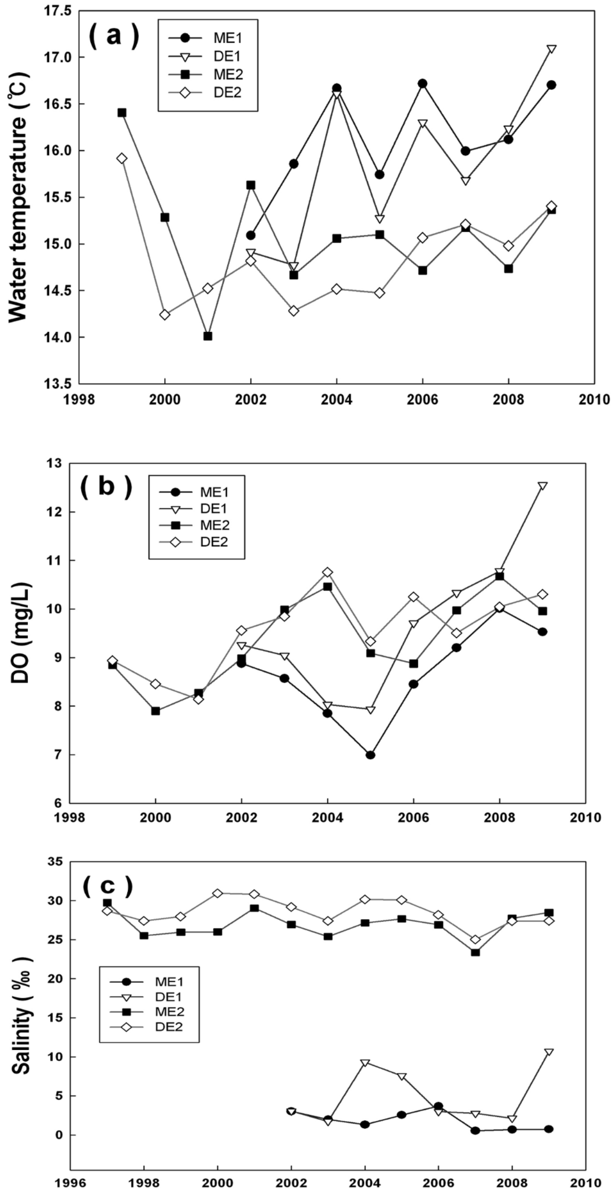

Fig. 2. Annual changes of water temperature (a), DO (b) and salinity (c).

Fish Fauna in the Mankyeong and the Dongjin River (2007~2009)

A total of 10 sampings conducted between 2007 and 2009 on the Mankyeong River and the Dongjin River revealed 3,727 fish of 66 species of 15 families (Table 1). The family Cyprinidae made up the majority of this figure (73.25%) at 2,730 fish of 33 species, followed by the family Mugilidae (12.21%) and the Clupeidae (5.34%).

In terms of individual species, a total of 744 counts of the *Zacco platypus* were observed, marking dominance at 19.96% of the total, followed by the *Chelon haematocheilus* at 414 counts (11.11%). These figures were followed by the *Hemibarbus labeo* (7.59%), *Opsariichthys uncirostris amurensis* (6.25%), *Pseudogobio esocinus* (5.15%), *Hemiculter eigenmanni* (4.75%) and the *Hemibarbus longirostris* (4.35%). A total of 18 Korean endemic species, including the *Acheilognathus yamatsutae*, were observed, and they made up 12.56% of the total fish count. 3 introduced species, including the *Carassius cuvieri, Micropterus salmoides* and the *Lepomis macrochirus*, were observed, making up 6.68% of the total count. One endangered species of the *L. obesus* was observed in 2008 at the Mankyeong River upstream. 19 seawater fish and peripheral fish species of the total of 66 species (28.78%) were collected in the Mankyeong River and the Dongjin River, which are inflown into the Yellow Sea. Among these fish species, the majority was collected at St.1 and St.4, and in the case of the family Mugilidae, they were also observed in St. 2 and St. 3, the central region of the Mankyeong River.

The comparison of the results of 3 years between 2007 and 2009 displayed a level of similarity without significant

Table 1. Numbers of fishes collected at sampling sites (2007-2009)

Family	Species name	Mankyeong River			Dongjin Rriver		Total	RA (%)	Remarks
		St. 1	St. 2	St. 3	St. 4	St. 5			
Engraulidae	*Coilia nasus*				2		2	0.05	Ph.
	Thryssa hamiltoni				10		10	0.27	Ph.
Clupeidae	*Sardinella zunasi*				129		129	3.46	Ph.
	Konosirus punctatus	4			66		70	1.88	Ph.
Cyprinidae	*Cyprinus carpio*	11	6		15	2	34	0.91	Pr.
	Carassius auratus	46	11	18	110		185	4.96	Pr.
	Carassius cuvieri	27	14		90	1	132	3.54	Ex. Pr.
	Rhodeus ocellatus	1					1	0.03	Pr.
	Rhodeus notatus			1			1	0.03	Pr.
	Acheilognathus lanceolatus					32	32	0.86	Pr.
	Acheilognathus yamatsutae			9			9	0.24	K. Pr.
	Acheilognathus rhombeus	9	6		3	4	22	0.59	Pr.
	Acanthorhodeus macropterus	25	4			4	33	0.89	Pr.
	Acanthorhodeus gracilis	13	4		5		22	0.59	K. Pr.
	Pseudorasbora parva	13	7		4	8	32	0.86	Pr.
	Pungtungia herzi			9		18	27	0.72	Pr.
	Coreoleuciscus splendidus			1			1	0.03	K. Pr.
	Sarcocheilichthys variegatus wakiyae	1	3	4			8	0.21	K. Pr.
	Sarcocheilichthys nigripinnismorii		4	7		3	14	0.38	K. Pr.
	Gnathopogon strigatus			2			2	0.05	Pr.
	Squalidus gracilis majimae			1			1	0.03	K. Pr.
	Squalidus japonicus coreanus	2	7	2			11	0.30	K. Pr.
	Squalidus chankaensis tsuchigae	8	10	51	18	16	103	2.76	K. Pr.
	Hemibarbus labeo	12	17	214	23	17	283	7.59	Pr.
	Hemibarbus longirostris			101		61	162	4.35	Pr.
	Pseudogobio esocinus		17	98	1	76	192	5.15	Pr.
	Abbottina rivularis	3	5				8	0.21	Pr.
	Microphysogobio yaluensis					7	7	0.19	K. Pr.
	Microphysogobio jeoni	72	1		7		80	2.15	K. Pr.
	Rhynchocypris oxycephalus					2	2	0.05	Pr.
	Aphyocypris chinensis			1			1	0.03	Pr.
	Zacco koreanus					22	22	0.59	K. Pr.
	Zacco platypus			382		362	744	19.96	Pr.
	Opsariichthys uncirostris amurensis	54	29	104	15	31	233	6.25	Pr.
	Squaliobarbus curriculus	5	2	2			9	0.24	Pr.
	Erythroculter erythropterus	76	60	4			140	3.76	Pr.
	Hemiculter eigenmanni	43	42		91	1	177	4.75	K. Pr.
Cobitidae	*Misgurnus anguillicaudatus*		1	1			2	0.05	Pr.
	Misgurnus mizolepis					1	1	0.03	Pr.
	Cobitis lutheri			1		1	2	0.05	Pr.
Bagridae	*Pseudobagrus fulvidraco*					1	1	0.03	Pr.
	Pseudobagrus koreanus			3		3	6	0.16	K. Pr.
Amblycipitidae	*Liobagrus mediadiposalis*					3	3	0.08	K. Pr.
	Liobagrus obesus			1			1	0.03	K. En. Pr.
Mugilidae	*Mugil cephalus*	21	1		19		41	1.10	Ph.
	Chelon haematocheilus	229	20	4	161		414	11.11	Ph.
Adrianichthyidae	*Oryzias latipes*			2			2	0.05	Pr.
Hemiramphidae	*Hyporhamphus intermedius*				4		4	0.11	Ph.
	Hyporhamphus sajori				1		1	0.03	Ph.
Cottidae	*Trachidermus fasciatus*	1	1		2		4	0.11	Ph.
Moronidae	*Lateolabrax japonicus*				10		10	0.27	Ph.
	Lateolabrax japonicus				2		2	0.05	Ph.
Centrarchidae	*Lepomis macrochirus*			9	1		10	0.27	Ex. Pr.
	Micropterus salmoides	23	22	14	33	15	107	2.87	Ex. Pr.
Leiognathidae	*Leiognathus nuchalis*				8		8	0.21	Ph.
Odontobutidae	*Odontobutis platycephala*					1	1	0.03	K. Pr.
	Odontobutis interrupta			1			1	0.03	K. Pr.

Table 1. Continued

Family	Species name	Mankyeong River			Dongjin Rriver		Total	RA (%)	Remarks
		St. 1	St. 2	St. 3	St. 4	St. 5			
Gobiidae	*Acanthogobius flavimanus*	4			35		39	1.05	Ph.
	Synechogobius hasta	4			10		14	0.38	Ph.
	Rhinogobius giurinus				1		1	0.03	Ph.
	Rhinogobius brunneus			47		6	53	1.42	Pr.
	Tridentger trigonocephalus	5			1		6	0.16	Ph.
	Tridentiger obscurus				9		9	0.24	Ph.
	Tridentiger brevispinis					17	17	0.46	Pr.
	Periophthalmus modestus				25		25	0.67	Ph.
	Periophthalmus magnuspinnatus	1					1	0.03	K. Ph.
	Number of species	27	24	29	32	27	66		
	Number of individuals	713	294	1,094	911	715	3,727		

RA, Relative Abundance; K, Korean endemic species; Ex, Exotic species; En, Endangered species; Pr, Primary freshwater fishes; Ph, Peripheral freshwater fishes

Table 2. Changes of dominance, diversity, evenness and richness index at each sampling sites from 2007 to 2009

	Dominance index			Diversity index			Evenness index			Richness index		
	2007	2008	2009	2007	2008	2009	2007	2008	2009	2007	2008	2009
St. 1	0.2154	0.2340	0.1035	1.9825	1.9041	2.5527	0.7321	0.7031	0.8032	2.8717	2.6499	3.8634
St. 2	0.2718	0.0914	0.1165	1.7770	2.4260	2.4143	0.7151	0.9193	0.8353	2.6866	2.9185	3.4019
St. 3	0.3302	0.1549	0.1991	1.5195	2.3007	1.8786	0.6599	0.6981	0.6776	1.7712	4.4151	2.3625
St. 4	0.2035	0.1534	0.1402	2.0184	2.0647	2.3825	0.6855	0.8309	0.7708	3.1256	2.1468	3.4685
St. 5	0.3745	0.2622	0.2770	1.5366	1.9870	1.8786	0.5991	0.6633	0.6271	2.6413	3.6068	3.1370

changes. In terms of observation by family, the family Cyprinidae was shown at the highest level in all 3 years, at 60.5, 78.9, and 75.3%. In the case of the family Mugilidae, which revealed high individual count, 2007 showed a high level at 23.8%, but the figure decreased to 13.2% in 2008 and 7.1% in 2009, with no significant changes to the individual count. Such decrease without changes in the individual count is caused by the increase in the number of species (32 species in 2007, 45 species in 2008 and 47 species in 2009) and increase in the presence of other significant fish species.

Analysis of the fish species composition by site (Table 2) showed the highest level of dominance in 2007 in all sites except St. 1. Species Diversity was the lowest in 2007 in all sites except St. 1, and in St.2, 3 and 5, sites above the midstreams of the Mankyeong River and the Dongjin River, and the value increased in 2008 before decreasing in 2009. Species Evenness was similar in all sites except St. 5 in 2007, and the value was the highest in St. 2 in 2008 and 2009. Species Richness was similar in 2007 in 3 sites excluding St. 3, and the sites showed significant differences when compared to one another in 2008 and 2009.

Changes of Fish Assemblages after Construction of the Saemangeum Dike

The observation of 40 species of 10 families in St. 1 and St. 4 of the Mankyeong River and Dongjin River downstreams between 2007 and 2009 following the construction of the Saemangeum Dike showed a figure similar to the 43 species and 20 families observed in a study conducted before construction (1979, 1982-1984, 1989-1990) (Table 3). However, there was a difference in species composition, as 14 primary freshwater fish species and 29 peripheral fish and seawater fish species were observed before dike construction and 21 primary freshwater fish species and 19 peripheral fish and seawater fish species were observed after dike construction. Furthermore, the percentage of primary freshwater fish of the total count increased significantly from 18% to 53%. The *Coilia mystus, Thryssa kammalensis, Pleuronichthys cornutus, Cynoglossus semilaevis* and the *Takifugu niphobles*, peripheral fish and seawater fish species observed in high numbers before dike construction, were not observed after construction, and dominant species of the *Sardinella zunasi, Konosirus punctatus* and the *Synechogobius hasta* showed decreased presence. Furthermore, primary freshwater fish species which were not collected before dike construction, such as the *C. cuvieri, M. jeoni, O. u. amurensis* and the *Erythroculter erythropterus*, were collected in high numbers after dike construction. Introduced species of the *C. cuvieri, M. salmoides* and the *L. macrochirus* were observed after dike construction, and this is assessed to affect future fish species composition.

Results of the cluster analysis of the findings before and after dike construction are organized in Fig. 3. With Coefficient of Similarity of 40 as the standard, there was a

Table 3. Changes of fish fauna the Mankyeong and the Dongjin River (St. 1, St. 4) from 1979 to 2009 (1979, Lee *et al*., (1980); 1982-1984, Kim and Lee (1984); 1989-1990, Lee (1990))

Family	Species name	1979	1982-1984	1989-1990	2007	2008	2009
Petromyzontidae	*Lampetra reissneri*		+				
Anguillidae	*Anguilla japonica*		+	+			
Congridae	*Conger myriaster*			+			
Engraulidae	*Coilia mystus*			+			
	Coilia nasus			+		+	
	Engraulis japonicus			+			
	Setipinna tenuifilis			+			
	Thryssa kammalensis			+			
	Thryssa hamiltoni			+		+	
Clupeidae	*Sardinella zunasi*	+		+	+		+
	Konosirus punctatus			+	+		
Cyprinidae	*Cyprinus carpio*				+	+	+
	Carassius auratus		+	+	+	+	+
	Carassius cuvieri				+	+	+
	Rhodeus ocellatus		+				+
	Acheilognathus rhombeus				+		+
	Acanthorhodeus macropterus					+	+
	Acanthorhodeus gracilis		+			+	+
	Pseudorasbora parva				+		+
	Sarcocheilichthys variegatus wakiyae						+
	Sarcocheilichthys nigripinnis morii		+				
	Gnathopogon strigatus		+				
	Squalidus japonicus coreanus		+			+	
	Squalidus chankaensis tsuchigae				+	+	+
	Hemibarbus labeo		+		+	+	+
	Pseudogobio esocinus						+
	Abbottina rivularis				+		+
	Microphysogobio jeoni				+	+	+
	Aphyocypris chinensis		+				
	Opsariichthys uncirostris amurensis				+	+	+
	Squaliobarbus curriculus					+	+
	Erythroculter erythropterus				+	+	+
	Hemiculter eigenmanni		+		+	+	+
Cobitidae	*Misgurnus anguillicaudatus*		+	+			
	Cobitis lutheri		+				
Bagridae	*Pseudobagrus fulvidraco*	+	+				
	Leiocassis nitidus		+				
Osmeridae	*Plecoglossus altivelis*		+				
Mugilidae	*Mugil cephalus*	+		+	+	+	+
	Chelon haematocheilus				+	+	+
Adrianichthyidae	*Hyporhamphus intermedius*			+			+
	Hyporhamphus sajori	+			+		
Platycephalidae	*Platycephalus indicus*			+			
	Collichthys lucidus			+			
Cottidae	*Trachidermus fasciatus*		+		+		+
Moronidae	*Lateolabrax japonicus*						+
	Lateolabrax japonicus				+		
Centrarchidae	*Lepomis macrochirus*				+		
	Micropterus salmoides				+		+
Leiognathidae	*Leiognathus nuchalis*						+
Gobiidae	*Acanthogobius flavimanus*						+
	Synechogobius hasta	+		+	+	+	+
	Rhinogobius giurinus						+
	Tridentger trigonocephalus			+	+		+
	Tridentiger obscurus					+	+
	Tridentiger barbatus			+			
	Periophthalmus modestus			+	+		+
	Periophthalmus magnuspinnatus						+

Table 3. Continued

Family	Species name	1979	1982-1984	1989-1990	2007	2008	2009
	Taenioides rubicundus			+			
Zoarcidae	*Zoarces gilli*			+			
Pholidae	*Pholis fangi*			+			
Pleuronectidae	*Pleuronichthys cornutus*			+			
Cynoglossidae	*Cynoglossus semilaevis*			+			
	Areliscus hollandi			+			
Monacanthidae	*Stephanolepis cirrhifer*			+			
Tetraodontidae	*Takifugu niphobles*			+			
	Number of species	5	17	28	24	19	33

Table 4. The similarity index of fish fauna between each study (1979-2009)

	1979	1982-1984	1989-1990	2007	2008	2009
1979		5.8824	10.7143	16.6667	10.5263	9.0909
1982-1984			10.7143	16.6667	26.3158	18.1818
1989-1990				25	17.8571	21.2121
2007					50	60.6061
2008						48.4849
2009						

distinction between the fish community of before Saemangeum Dike construction and after Saemangeum Dike construction (2007, 2008, and 2009). Coefficient of Similarity by year showed the highest value at approximately 60% in 2007 and 2009 (Table 4).

Discussion

In the case of streams flow into the sea, downstream salinity is controlled via aquatic environment factors such as nutrients, chlorophyll and productivity (Sharp *et al*., 1982, D'Elia *et al*., 1983). Currently, the Saemangeum Dike is undergoing desalination after decrease in the movement of seawater as a result of dike construction works. However, with increase in size, the salinity level within dike between 1997 and 2009 did not display significant differences. However, there has been continuous fresh water influx from the Mankyeong River and the Dongjin River, and the lack of passage through sea dike sluice is predicted to lead to decrease in salinity.

Physical, chemical and biological changes in the habitat change the species composition of fish living in brackish water zone (Amisah and Cowx, 2000; Raat, 2001; Eklov *et al*., 2002; Kruk, 2007; Leung *et al*., 2009). The majority of fish living in brackish water zone is able to live in a wide range of salinity level, and they move to areas of higher salinity when faced with changes in the salinity of their original habitat as a result of increased fresh water influx (Moyle and Cech, 2000). Such adaptability is expected to hold the key to survival by peripheral fish and seawater fish inhabiting Saemangeum, which is undergoing reclamation. Furthermore, such changes in salinity are assessed to

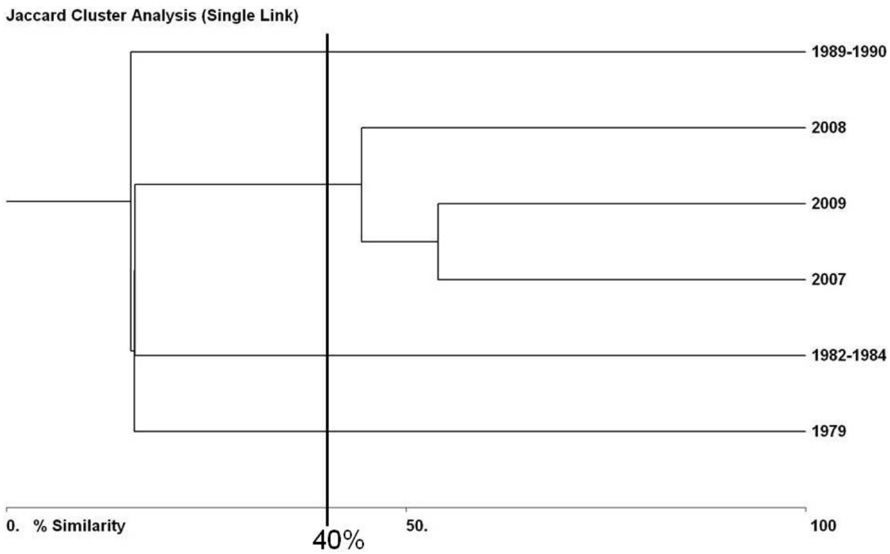

Fig. 3. Cluster analysis using presence-absence fish species data in each sampling occasions in the Mankyeong and the Dongjin River (only data from St. 1 and St. 4 were used for analysis).

expand freshwater fish habitat to downstreams of the Mankyeong River and the Dongjin River.

Comparison of the mid and downstream fish fauna of the Mankyeong River and the Dongjin River before and after Saemangeum Dike construction has revealed decrease in peripheral fish and seawater fish and increase in primary freshwater fish. Since there have been differences with regards to study methods and times, it is difficult to confirm if the result is caused by desalination following dike construction. However, study by Sim and Lee (1999) has predicted decreased in the number of peripheral fish, such as families Callionymidae and Gobiidae, found in mudflats as a result of sediment buildup and decreased salinity caused by weak seawater circulation following the completion of dike construction, and this study also observed a similar finding. Desalination and seawater movement caused by decreased salinity as a result of tide decrease are expected to affect introduced species observed in the Mankyeong River and the Dongjin River. 3 introduced species of the *C. cuvieri, M. salmoides* and the *L. macrochirus* observed in the Mankyeong River and Dongjin River area between 2007 and 2009 are all species which prefer flat water as their habitat. Therefore, desalination of Lake Saemangeum is expected to lead to the increase in fish distribution, and this is assessed to affect the existing fish community.

Since changes in the ecosystem caused by environmental changes generally occur over a long period of time, with the exception cases in such as direct injection of poisonous substances or pollutants, the lack of long-term studies may lead to major problems with environmental protection and management (Magnuson, 1990). Estuary-related studies are especially prone to either over-assessment or under-assessment as a result of the differences in species observed depending on the time of the study. Furthermore, analysis of short-term study data also faces the problem of human errors (Penczak *et al*., 1998).

The Saemangeum Dike construction was a large scale construction which took 15 years, and it is predicted that it will take long time to change the lake environment within the dike, as the lake is 401 km^2 wide. Furthermore, in the case of Saemangeum, a large-scale civil engineering work is planned for between 2006 and 2020 on a scale similar to that of reclamation projects and multifunctional city construction. Significant changes in the ecosystem of Lake Saemangeum are expected to occur with the completion of the Saemangeum Project in 2020. Results of the 3 years of study on the fish community of the Mankyeong River and the Dongjin River conducted from 2007, the time of completion of the Saemangeum Dike, did not display significant differences by year. In such way, there are difficulties when attempting to analyze ecological changes of Saemangeum, which is undergoing continuous environmental changes over a long period of time. Therefore, there is a need for long-term studies on fish community within Lake Saemangeum, and studies which incorporate attached algae, phytoplankton, zooplankton and other aquatic invertebrates in addition to fish species, will be able to provide effective and useful data for the restoration of the Saemangeum ecology.

Acknowledgments

This study was supported by the Korean National Long-Term Ecological research from the Ministry of Environment, Republic of Korea.

References

Amisah, S. and I. Cowx (2000) Response of the fish populations of the River Don in South Yorkshire to water quality and habitat improvements, Environmental Pollution 108: 191-199.

Barry, W.M. (1990) Fishways for Queensland coastal streams; an urgent review. In: Proceedings of the International Symposium on Fishways '90, Gifu, Japan.

Buisson, L., L. Blanc and G. Grenouillet (2007) Modeling stream fish species distribution in a river network: the relative effects of temperature versus physical factors, Ecol. Freshw. Fish 17: 144-157.

D'Elia, C.F., D.M. Nelson and W.R. Boynton (1983) Chesapeake Bay nutrient and plankton dynamics: III. The annual cycle of dissolved silicon, Geochim, cosmochim. Acta, 47: 1945-1955.

Eklov, A., L. Greenberg, C. Bronmark, P. Larsson, and O. Berglund (2002) Response of stream fish to improved water quality: a comparison between the 1960s and 1990s, Freshwater Biology 40: 771-782.

Fishbase (2012) http://www.fishbase.org

Kim, I.S., Y. Choi, C.L. Lee , Y.J. Lee, B.J. Kim and J.H. Kim (2005) Illustrated book of Korean fishes, Kyohak publishing, Seoul.

Kim, I.S. and W.O. Lee (1984) Effects of Stream Modification in the Seomjin River on the Fish Communities of the Dongjin River in Korea, Bull. Korean Fish. Soc., 17(6): 549-556.

Kim, I.S. and J.Y. Park (2002) Freshwater fish of Korea. Kyo-Hak Publishing. Seoul.

Kim, I.S. and H. Yang (2001) Fish Community Changes of the Buan Dam, Korea, Korean J. Ecol. 24(1): 45-50.

Kouamlan, E.P., G.G. Teugels, V. N'Douba, G.G. Bi and T. Kon (2003) Fish diversity and its relationships with environmental variables in a West African basin, Hydrobiologia 505: 139-146.

Kruk, A. (2007) Role of habitat degradation in determining fish distribution and abundance along the lowland Warta River, Poland, Journal of Applied Ichthyology 23: 9-18.

Kwak, S.N. and S.H. Huh (2003) Changes in Species Composition of Fishes in the Nakdong River Estuary, J. Kor. Fish. Soc. 36(2): 129-135.

Lee, C.Y. (1990) The Structure and Function of Estuarine Ecosystem of Mangyong River, Korean J. Ecol. 13(4): 267-283.

Lee, C.Y., I.B. Yoon and I.S. Kim (1980) A Study on the Dynamics of Fish Community in Mangeong River, Korean J. Limnol. 13: 1-2.

Lee, T.W. (1991) The demersal fishes of Asan Bay. I. Optimal sample size, Bull. Kor. Fish. Soc. 24: 248-254.

Lee, T.W. (1993) The demersal fishes of Asan Bay. III. Spatial variation in abundance and species composition, J. Kor.. Fish. Soc. 26: 438-445.

Lee, T.W. (1996) Change in species composition of fish in Chonsu Bay. 1. Demersal fish, Bull. Kor. Fish. Soc. 29: 71-83.

Lee, T.W. (1998) Change in species composition of fish in Chonsu Bay. 3. Pelagic fish, J. Kor. Fish. Soc. 31: 645-664.

Lee, T.W., H.T. Moon and G.C. Kim (2003) Seasonal Variation in Species Composition of Fish in the Estuary of Saemangeum Waters during the Construction of a Dike in 2001-2002, J. Kor. Fish. Soc. 36(3): 298-305.

Leung, E., J. Rosenfeld and J. Bernhardt (2009) Habitat effects on invertebrate drift in a small trout stream: implications for prey availability to drift-feeding fish, Hydrobiologia 623: 113-125.

Magnuson, J.J. (1990) Long-Term Ecological Research and the Invisible Rresent, BioScience 40(7).

Mallen-Cooper, M. and J. Harris (1990) Fishways in Mainland South-Eastern Australia. In: Proceedings of the International Symposium on Fishways '90, 221-230.

Margalef (1958) R. Margalef, Information theory in ecology, General Systems 3 pp. 36-71.

Matthews, W.J. and H.W. Robison (1988) The distribution of the fishes of Arkansas: a multivariate analysis, Copeia pp. 358-374.

Matthews, W.J., D.J. Hough and H.W. Robison (1992) Similarities in fish distribution and water quality patterns in streams of Arkansas: congruence of multivariate analysis, Copeia pp. 296-305.

Meng, A.G.K. (1973) Origin of the freshwater fish fauna of India, Curr. Sci. 42(16): 553-556.

Moyle, P.B. and J.J. Cech Jr. (2000) Fishes: an introduction to ichthyology (4th edition). Prentice Hall Inc. New Jersey 437 pp.

Nelson, J.S. (1994) Fishes of the world (3rd edition), John Wiley & Sons, New York.

Penczak, T., L. Glowacki, W. Galicka and H. Koszalinski (1998) A long-term study (1985-1995) of fish populations in the impounded Warta River, Poland, Hydrobiologia, 368: 157-173.

Pielou, E.C. (1969) Shannon's formula as a measure of specific diversity: It's use and misuse, Amur. Nat. 100: 463-465.

Raat, A. (2001) Ecological rehabilitation of the Dutch part of the River Rhine with special attention to the fish. Regulated Rivers: Research & Management, 17: 131-144.

Seo, J.W. and H.S. Kim (2009) A Study of Fish Community on Up and Downstream of Hwabuk Dam Under Construction in the Upper Wie Stream, Korean J. Limnol. 42(2): 260-269.

Shannon, C.E. and W. Wiener (1949) The mathematical theory of communication. University of Illinois press, Urbana.

Sharp, J. H., C.H. Culberson and T.M. Church (1982) The chemistry of the Delaware Estuary. General considerations, Limnol. Oceanogr. 27: 1015-1028.

Sim, K.S. and C.R. Lee (1999) Fish fauna of the Saemangeum area in the west coast of Chollabuk-do. Korea, Kor. J. Environ. Biol. 17: 617-627.

Simpson, E.H. (1949) Measurement of diversity, Nature 163: 688

Thiel, R., A. Sepulveda, R. Kafemann and W. Nellen (1995) Environmental factors as forces structuring the fish community of the Elbe Estuary, J. Fish Biol. 46: 47-69.

Yang, H.J., K.H. Kim and J.D. Kum (2001) The Fish Fauna and Migration of the Fishes in the Fish Way of the Nakdong River Mouth Dam, Korean J. Limnol. 34(3): 251-258.

Received 23 May 2011; Revised (1st: 10 June 2011); Accepted 11 June 2011